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PATENT & TRADEMARK OFFICE

Docket No.: S1022.80494US00
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	Tomas NORDSTRÖM, Daniel BENGTSSON, and Olivier ISSON		
Serial No.:	09/737155		
Filed:	December 14, 2000	Issued:	January 17, 2006
Serial No.	09/737,155	Patent No.:	6,987,800 B2
For:	DSL TRANSMISSION SYSTEM WITH FAR-END CROSSTALK CANCELLATION		
Examiner:	Emmanuel Bayard		
Art Unit:	2631	Confirmation No.:	8195

Certificate
JAN 27 2006
of Correction

Certificate of Mailing Under 37 CFR 1.8(a)
I hereby certify that this paper (along with any paper referred to as being attached or enclosed) is being deposited with the U.S. Postal Service on the date shown below with sufficient postage as First Class Mail, in an envelope addressed to: Attention: Certificate of Correction Branch, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

Dated: January 23, 2006

Gail Driscoll

REQUEST FOR CERTIFICATE OF CORRECTION
PURSUANT TO 37 CFR 1.322

Attention: Certificate of Correction Branch
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir/Madam:

Upon reviewing the above-identified patent, Patentee noted a typographical error which should be corrected.

In the Specification:

The equation found in column 4, line 35 of U.S. Patent No. 6,987,800, reproduced below, is incorrect.

$$\mathrm{FEXT(fj)} = \sum_{l=1}^{n} Hlp(fl)Sl(fj),\ l \neq p$$

The same equation, found on page 6 of the application as filed is reproduced below.

$$\mathrm{FEXT(fj)} = \sum_{l=1}^{n} Hlp(fj)Sl(fj),\ l \neq p$$

JAN 30 2006

The error, located between the second set of parenthesis, was not in the application as filed by applicant. No amendment was made by either the Examiner or Patentee changing "(fj)" to "(fl)" as it appears in the equation of U.S. Patent No. 6,987,800.

In support of this request Patentee encloses highlighted copies of page 6 of the application as filed and column 4 of issued U.S. Patent No. 6,987,800. Also enclosed is PTO form SB/44.

The correction requested does not involve change in the patent that constitutes new matter or would require reexamination. Therefore, it is respectfully requested that the corrections be made and that a Certificate of Correction be issued.

Patentees respectfully submit that, since the error for which a Certificate of Correction is sought was the result of Patent Office mistake, no fee is due. However, if the Examiner deems a fee necessary, the fee may be charged to the account of the undersigned, Deposit Account No. 23/2825. Should any questions arise concerning the foregoing, please contact the undersigned at the telephone number listed below.

Dated: January 23, 2006

Respectfully submitted,

By [signature]

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JAN 30 2006

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TRANSMITTAL FORM

(to be used for all correspondence after initial filing)

Application Number	Patent#: 6987800 B2
Filing Date	Issued: January 17, 2006
First Named Inventor	Thomas Nordström
Art Unit	2631
Examiner Name	Emmanuel Bayard
Attorney Docket Number	S1022.80494US00
Total Number of Pages in This Submission	

ENCLOSURES (*Check all that apply*)

- [ ] Fee Transmittal Form
  - [ ] Fee Attached
- [ ] Amendment/Reply
  - [ ] After Final
  - [ ] Affidavits/declaration(s)
- [ ] Extension of Time Request
- [ ] Express Abandonment Request
- [x] Certificate of Correction
- [x] Request for Certificate of Correction
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  - [ ] Reply to Missing Parts under 37 CFR 1.52 or 1.53
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- [ ] CD, Number of CD(s) ______
  - [ ] Landscape Table on CD
- [ ] After Allowance Communication to TC
- [ ] Appeal Communication to Board of Appeals and Interferences
- [ ] Appeal Communication to TC **(Appeal Notice, Brief, Reply Brief)**
- [ ] Proprietary Information
- [ ] Status Letter
- [x] Other Enclosure(s) (please Identify below):

Copy of Page 6 of the Apl as Filed
Copy of Col. 9 of US 6,987,800
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Remarks

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

Firm Name	WOLF, GREENFIELD & SACKS, P.C.		
Signature	[signature]		
Printed name	James H. Morris		
Date	January 23, 2006	Reg. No.	34,681

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Dated: January 23, 2006 Signature: Gail Driscoll (Gail Driscoll)

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PTO/SB/44 (04-05)
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U.S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

(Also Form PTO-1050)

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 6987800 B2

APPLICATION NO. : 09/737155

ISSUE DATE : January 17, 2006

INVENTOR(S) : Thomas Nordström, Daniel Bengtsson and Olivier Isson

It is certified that an error appears or errors appear in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Col. 4, line 35 should read:

$$\mathrm{FEXT}(fj) = \sum_{l=1}^{n} Hlp(fj)Sl(fj)\,,\ l \neq p$$

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JAN 30 2006

frequency fj.

The FEXT interference for a given frequency fj and for a modem p can therefore be written:

$$\mathrm{FEXT}(fj) = \sum_{l=1}^{n} Hlp(fj)Sl(fj)\,,\ l \neq p$$

According to the first embodiment of the invention, the complex values Sl(fj), l=1...n, l≠p are approximated by the symbols $\hat{S}$l(fj), i.e. by the symbols of the constellation coming the closest to the respective received frequency components Rl(fj), l=1...n, l≠p, respectively output by the demappers 37. This implies that the processing in the modem p is one-symbol delayed with respect to the other modems.

The complex symbols $\hat{S}$l(fj) from the other modems, l=1...n, l≠p, are then linearly combined in block 34 and subtracted by a subtractor 31 from the received frequency component Rp(fj) to produce a FEXT-removed complex value Tp(fj). The demapper 37 of modem p outputs a demapped word $\hat{X}$p(fj) and the corresponding constellation point $\hat{S}$p(fj). The complex value $\hat{S}$p(fj) is subtracted from the complex value Tp(fj) to produce an error value. This error value is squared in a circuit 32 and processed in a block 33 to update the coefficients of the linear combination, for example according to the known steepest gradient algorithm. The updated values stored in block 33 will be used for FEXT canceling the next frequency component Rp(fj), i.e. the frequency component Rp(fj) of the next incoming block. After a few iterations, the linear combination coefficients converge towards the values Hlp(fj) of the transfer matrix.

We have considered above FEXT cancellation at a single tone fj. It is clear however that the processing should be repeated for all the tones j=1 to N, the frequency coefficients Rp(fj) being sequentially output by the parallel to serial converter 36. The linear combination coefficients for each frequency fj are stored in the memory of block 33. After a few iterations the memory contains the values Hlp(fj), l=1...n and l≠p, j=1...N.

We have assumed above that the FEXT at the different frequencies could be independently canceled. In a conventional DMT transmission system this can only be regarded as an approximation since the limited duration of the time domain blocks causes a spreading of the frequency components. Generally, the FEXT at a frequency fj depends also

transforming said discrete multitone signals into a discrete multitone symbol of frequency components and demapping means outputting for each frequency component the symbol of the constellation nearest thereto and the corresponding demodulated data; estimation means, in at least one line termination modem, for estimating the constellation symbols actually sent by the network termination modems, from the frequency components of the discrete multitone symbols received by all modems; calculation means for calculating a linear combination of said estimated modulated data, for subtracting said linear combination from the frequency components of said at least one line termination modem and for applying a resulting difference to the demapping means of said at least one termination modem; error calculation means for calculating the error distance between the constellation symbol from said at least one line termination modem and said difference; and updating means for updating the coefficients of said linear combination as a function of said error distance.

The invention also provides a far-end crosstalk canceling method for a digital subscriber line transmission system, said transmission system comprising a plurality of line termination modems receiving discrete multitone signals from corresponding network termination modems over a plurality of transmission channels, each line termination modem comprising frequency transforming means for transforming said discrete multitone signals into a discrete multitone symbol of frequency components, and demapping means outputting for each frequency component the symbol of the constellation nearest thereto and the corresponding demodulated data, the method comprising the steps of: estimating, for at least one line termination modem, the constellation symbols actually sent by all the modems from the frequency components of the discrete multitone symbols received by said modems; calculating a linear combination of said estimated symbols, subtracting said linear combination from the frequency components of a discrete multitone symbol and applying the resulting difference to the demapping means of said at least one modem, to obtain a constellation symbol; calculating the error distance between said constellation symbol and said difference; and updating the coefficients of said linear combination as a function of said error distance.

The foregoing and other objects, features, aspects and advantages of the invention will become apparent from the following detailed description of embodiments, given by way of illustration and not of limitation with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**, previously described, schematically shows the structure of a modem suitable for use in a DSL transmission system;

FIG. **2**, previously described, schematically shows the different types of noise occurring in a DSL transmission system;

FIG. **3** shows a first and a second embodiment of a FEXT canceller according to the invention;

FIG. **4** shows a third embodiment of a FEXT canceller according to the invention;

FIG. **5** shows a fourth embodiment of a FEXT canceller according to the invention; and

FIG. **6** schematically shows the overall structure of a DSL transmission system comprising a FEXT canceller according to the third or the fourth embodiment of the invention.

DETAILED DESCRIPTION

The invention is based on the idea that the actual value of a symbol causing FEXT interference at the LT side can be obtained from the modem receiving this symbol. The modem receiving the FEXT interfering symbol and the modem receiving the FEXT corrupted symbol being both located at the central office, a connection between the two modems can be realized.

FIG. **3** shows a first embodiment of the invention and more specifically a part of the receiver TX of a modem p on the LT side, receiving a FEXT corrupted signal. In this embodiment the blocks **38** and **39** represented with dotted lines do not exist.

Each modem i on the LT side is connected to a modem c(i) on the NT side through a transmission channel. The blocks **35, 36, 37** correspond to the blocks **15, 16, 17** of the receiver RX illustrated in FIG. **1**.

This first embodiment aims at canceling the FEXT interference caused by the signals transmitted by n-1 modems c(i), i=1 to n, i≠p.

For clarity purpose, suppose first that a symbol carried by the subcarrier or tone fj is FEXT corrupted by symbols at the same frequency only. If, as illustrated on FIG. **2**, $H(fj)=(H_{kl}(fj))$ the transfer matrix of the n transmission channels from the NT to the LT side, with k,l=1 . . . n, fj being the frequency index with j=1 . . . n, we can write in the frequency domain for the frequency fj:

$$R(fj)=H(fj)*S(fj),$$

where R(fj)=Rk(fj), k=1 . . . n, is the vector of the received frequency components and S(fj)=Sk(fj), k=1 . . . n, is the vector of the transmitted DMT symbols from the n modems, for the frequency fj.

The FEXT interference for a given frequency fj and for a modem p can therefore be written:

$$FEXT(fj) = \sum_{l=1}^{n} Hlp(fj)Sl(fj),\ l \neq p$$

According to the first embodiment of the invention, the complex values Sl(fj), l=1 . . . n, l≠p are approximated by the symbols $\hat{S}$l(fj), i.e. by the symbols of the constellation coming the closest to the respective received frequency components Rl(fj), l=1 . . . n, l≠p, respectively output by the demappers **37**. This implies that the processing in the modem p is one-symbol delayed with respect to the other modems.

The complex symbols $\hat{S}$l(fj) from the other modems, l=1. . . n, l≠p, are then linearly combined in block **34** and subtracted by a subtractor **31** from the received frequency component Rp(fj) to produce a FEXT-removed complex value Tp(fj). The demapper **37** of modem p outputs a demapped word $\hat{X}$p(fj) and the corresponding constellation point $\hat{S}$p(fj). The complex value $\hat{S}$p(fj) is subtracted from the complex value Tp(fj) to produce an error value. This error value is squared in a circuit **32** and processed in a block **33** to update the coefficients of the linear combination, for example according to the known steepest gradient algorithm. The updated values stored in block **33** will be used for FEXT canceling the next frequency component Rp(fj), i.e. the frequency component Rp(fj) of the next incoming block. After a few iterations, the linear combination coefficients converge towards the values Hlp(fj) of the transfer matrix.

We have considered above FEXT cancellation at a single tone fj. It is clear however that the processing should be repeated for all the tones j=1 to N, the frequency coefficients Rp(fj) being sequentially output by the parallel to serial converter **36**. The linear combination coefficients for each